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Re-examination of the Murchison Downs meteorite: A fragment of the Dalgaranga mesosiderite?

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Abstract

The Murchison Downs mesosiderite was reportedly recovered in 1925 from a locality *ca.* 200 km to the NE of the crater- forming Dalgaranga mesosiderite in Western Australia. A comparison of data from the literature on the chemistry and mineralogy of Murchison Downs and Dalgaranga, and a re-investigation of the metallography and mineralogy of Murchison Downs and Dalgaranga, suggests strongly that the two meteorites belong to the same fall. Murchison Downs may be one of the few examples of a meteorite transported by Aborigines and, pending further work, should be paired with the Dalgaranga meteorite.

Introduction

Meteorites have been recovered throughout Western Australia over the last century. Currently, specimens from 141 distinct meteorites have been documented from the State, representing more than 50% of all meteorites known from Australia (Bevan 1992). Conventionally, meteorites take the name of the geographical locality where they fell or were found. 'Paired' meteorites are those suggested, because of geographical propinquity and classification, to belong to a single fall (Hey 1966). However, when two or more meteorites were found at different times and allocated different names, but were subsequently proved conclusively to be from the same fall or find, then they are said to be 'synonymous' and the name of the meteorite first recovered usually takes precedence. Conversely, meteorites thought to be from the same fall are sometimes found on further examination to be distinct. For these reasons, the number of distinct meteorites known from Western Australia has fluctuated in the past without necessarily any addition of new material.

The Murchison Downs meteorite (Western Australian Museum registration number WAM 12586), a small metallic slug weighing 33.5 grams (Figure 1), was found in 1925 and described briefly by Simpson (1927), who noted that an etched surface of the meteorite displayed a Widmanstätten pattern and classified the meteorite as an iron with a fine octahedral (Of) structure (*e.g.* see Graham *et al.* 1985). Recently, Wasson *et al.* (1989) have provided a modern analysis of the Murchison Downs meteorite showing that it is a metallic nodule from a mesosiderite. In this paper, metallographic, mineralogical and chemical data are presented suggesting that the Murchison Downs meteorite is probably a transported fragment of the Dalgaranga mesosiderite.

Figure 1. The Murchison Downs meteorite (Western Australian Museum number 12586).

Recovery and historical details

Few details of the discovery of the Murchison Downs meteorite are known. Neither the exact locality, nor the name of the finder was recorded. In the Annual Report of the Geological Survey of Western Australia for 1925, Gibb Maitland records the find-site as Murchison Downs Station in the Kyarra district of the Murchison Division and notes the 'donor' of the specimen (GSWA 1/3894) as "Richardson". Simpson (1927) records the co-ordinates of the find-site as approximately 26° 40'S, 119° 0'E which correspond to a site close to 'North Cattle Well', situated *ca.* 15 km north of the homestead on 'Murchison Downs' Station and approximately 200 km to the north-east of the Dalgaranga crater. Since Simpson's (1927) observations were made, no detailed metallographic description of the meteorite has been published. However, McCall and de Laeter (1965) noted that the Murchison Downs meteorite "was similar to the small twisted irons commonly found near meteorite craters."

In contrast, the discovery of the Dalgaranga crater and recovery of its associated meteorites are well documented. This small crater, measuring 25 m in diameter, was discovered in 1923 by G E P Wellard at co-ordinates 27° 43'S, 117° 15'E on Dalgaranga Station, north of Yalgoo (Simpson 1938). Wellard is reported to have recovered a large number of meteorite fragments from the vicinity of the crater but the repository of this material is unknown. Simpson (1938) described a metallic fragment of the Dalgaranga meteorite weighing 42 grams, which he classified as a medium (Om) octahedrite.

In 1959, and again in 1960, H H Nininger and G I Huss of the American Meteorite Laboratory visited the Dalgaranga crater and from the surrounding plain collected 207 specimens with an aggregate weight of 1098 grams. In addition, they recovered 280 specimens, weighing approximately 9.1 kg, of deeply weathered material buried beneath the crater floor (Nininger & Huss 1960). Most of the specimens from the plain around the crater weighed individually less than 5 grams, and the largest weighed 57 grams. The material comprises both metallic and achondritic stony portions and the classification of the meteorite as a mesosiderite by Nininger & Huss (1960) was later confirmed by McCall (1965).

Metallographic, mineralogical and chemical details

A metallographic examination (this work) of an etched section (1.5 x 1.5 cm) of the Murchison Downs meteorite (WAM 12586—formerly Geological Survey of Western Australia Collection 1/3894) reveals that this meteorite consists predominantly of plates of α-Fe,Ni (kamacite), γ-Fe,Ni (taenite), γ'-Fe,Ni (tetrataenite) and $\alpha+\gamma$ Fe,Ni (plessite) in octahedral arrangement. On two perpendicular sections, the bandwidths of plates of kamacite (excluding those in plessite) vary from 0.3-0.5 mm with a mean of 0.45±0.1 mm. This kamacite bandwidth lies within the 'fine octahedrite' group of the modern structural classification of iron meteorites (Buchwald 1975). Troilite and schreibersite occur as irregular inclusions, and several small (mm-sized) inclusions of non-metallic minerals composed of low-Ca orthopyroxene (Fs_{34}), anorthitic plagioclase feldspar (An_{91}),

Table 1
Electron microprobe analyses of non-metallic minerals in the Murchison Downs and Dalgaranga meteorites.
Analysts: B J Griffin and G D Pooley. - indicates not detected

	Murchison Downs				Dalgaranga	
	orthopyroxene	plagioclase		chromite	chromite	range[a]
SiO_2	52.7	46.2		-	-	
TiO_2	0.32	-		1.20	1.32	0.18-1.32
Al_2O_3	0.69	34.3		10.8	13.5	13.0-14.3
Cr_2O_3	-	-		54.6	52.0	51.3-52.41
V_2O_3	-	-		0.54	0.52	0.47-0.62
FeO[b]	21.1	-		28.6	28.2	27.0-28.2
MnO	0.83	-		1.74	1.60	1.50-1.88
MgO	22.6	-		2.70	3.54	3.42-4.19
CaO	1.80	18.4		-	-	
Na_2O	-	0.93		-	-	
K_2O	-	0.00		-	-	
Totals	100.04	99.83		100.18	100.68	
Molecular %						
	Fs_{34}	$An_{91.6}$	ulvospinel	3.1	3.3	
	$En_{62.4}$	$Ab_{8.4}$	spinel	21.9	26.8	
	$Wo_{3.6}$	$Or_{0.0}$	chromite	74.3	69.1	
			magnetite	0.7	0.7	
			100Cr/(Cr+Al)	77.2	72.0	
			100Fe/(Fe+Mg)	85.6	81.7	

[a]range based on six analyses. [b]All Fe reported as FeO.

Al-rich chromite and a silica polymorph occur throughout the section. These inclusions are swathed with bands of kamacite up to 1.0 mm thick. Electron microprobe analyses of the non-metallic minerals in the Murchison Downs meteorite are given in Table 1.

The Widmanstätten pattern displayed by the Murchison Downs meteorite is not continuous; in addition to swathing kamacite around silicate inclusions, in the section examined a thick (1.00 mm) band of swathing kamacite partly bounds the external surface of the meteorite. Locally, the Widmanstätten structure displays moderate to severe mechanical deformation and kamacite and taenite plates are bent and kneaded. Kamacite is shock-hardened, displaying the cross-hatched ε-kamacite structure and abundant Neumann bands. Narrow zones of shear deformation occur in the metallic micro-structure of the meteorite along which fine scale (<1 μm) recrystallization has taken place. Under crossed polars, troilite displays abundant shock-twins and, where inclusions are traversed by shear zones, troilite has been recrystallized.

Table 2

Summary of the mineralogy of the Murchison Downs and Dalgaranga mesosiderites (mineral compositions determined by electron microprobe analyser unless otherwise stated - indicates not recorded)

	Murchison Downs		Dalgaranga			
	Wasson *et al.* (1989)	This work	Hassanzadeh *et al.* (1990)	McCall (1965)	Nehru *et al.* (1980)	This work
silicates						
olivine	-	-	-	Fa_{13} [a]	Fa_{13-38}	-
orthopyroxene	$Fs_{25}En_{73}Wo_2$	$Fs_{34}En_{62.4}Wo_{3.6}$	present	Fs_{34} [b]	-	-
plagioclase	$An_{90\pm1}Ab_{9\pm1}$	$An_{91.6}Ab_{8.4}$	anorthite	$An_{72}Ab_{28}$ [b]	-	-
silica polymorph	present	present	-	-	-	present
metallic minerals						
kamacite (mm bandwidth)	(0.5)	(0.45±0.1)	$Fe_{93.6}Ni_{5.8}Co_{0.53}$ (0.3±0.1)	-	-	present
taenite	present	present	present	-	-	present
tetrataenite	present	present	$Fe_{48.3}Ni_{51.6}Co_{0.09}$	-	-	present
other minerals						
troilite	present	present	present	present	-	present
chromite	present	$Usp_{3.1}Sp_{21.9}Chr_{74.3}Mt_{0.7}$	present (Al-rich)	present	-	$Usp_{3.3}Sp_{26.8}Chr_{69.1}Mt_{0.7}$
schreibersite	present	present	present	-	-	present
cohenite	-	present	-	-	-	present

[a] determined by X-ray diffraction; [b] determined optically.

The Dalgaranga meteorite has been described by Nininger & Huss (1960) and McCall (1965). The material consists of disrupted fragments of mesosiderite; individual specimens ranging from nodules formed almost entirely of metal, through mixtures of metal and silicate, to essentially basaltic achondritic material. Nininger & Huss (1960) noted that those fragments composed mainly of metal are polycrystalline and display Widmanstätten patterns ranging from coarsest (Ogg) to finest (Off) octahedrite. The structures of many of these metallic slugs show extensive gross mechanical deformation and localised thermal alteration of the type often encountered in crater-forming iron meteorites. Other fragments show few signs of the effects of impact shock-metamorphism (Nininger & Huss 1960). Hassanzadeh *et al.* (1990) have described a metallic slug from the Dalgaranga meteorite and note the presence of clumps of silicates that comprise low-Ca pyroxene, anorthite, accessory troilite, schreibersite and an Al-rich chromite.

Published mineralogical data for both Murchison Downs and Dalgaranga meteorites (and those determined in this work) are summarised in Table 2. Simpson (1938), Wasson

Table 3

Summary of published analyses of metal in the Murchison Downs and Dalgaranga mesosiderites

	Ni (%)	Co (%)	Ga μg/g	Ge μg/g	Ir μg/g	Cr μg/g	Cu μg/g	As μg/g	Sb ng/g	W ng/g	Re ng/g	Pt μg/g	Au μg/g
Murchison Downs[1]	9.16	0.49	13.6	56.1	4.98	221	144	12.5	310	1110	600	8.9	1.32
Dalgaranga [2]	10.27	0.48	12.7	-	4.99	12	172	11.9	260	990	600	8.0	1.37
Dalgaranga [3]	8.8	-	15.5	56.0	4.2	-	-	-	-	-	-	-	-
Dalgaranga [4]	8.63	-	-	-	-	-	-	-	-	-	-	-	-

[1] Wasson *et al.* (1989); [2] Hassanzadeh *et al.* (1990); [3] Wasson *et al.* (1974); [4] Simpson (1938)

et al. (1974) and Hassanzadeh *et al.* (1990) have analysed the metal in the Dalgaranga meteorite, and their data, compared with those of Wasson *et al.* (1989) for the Murchison Downs meteorite, are shown in Table 3

Discussion

Excluding olivine, the silicate mineralogy of both the Dalgaranga and Murchison Downs meteorites consists essentially of low-Ca orthopyroxene and anorthite. Accessory minerals in both meteorites include troilite, schreibersite and an Al-rich chromite. In the Murchison Downs meteorite, Wasson *et al.* (1989) reported a fine-grained silica polymorph, probably tridymite, which is confirmed in this work. In the Dalgaranga meteorite, olivine with the range of compositions Fo_{87-62} Fa_{13-38} (Nehru *et al.* 1980), generally occurs as nodules and phenocrysts in the stony portions of the meteorite (McCall 1965). Olivine has not been found in the Murchison Downs meteorite. However, in mesosiderites, olivine is only rarely associated with metallic nodules. Additionally, tridymite has yet to be reported from the Dalgaranga meteorite, although Hassanzadeh *et al.* (1990) note that it is a sub-group 'A' mesosiderite that are known to be tridymite-rich (Hewins 1984). Nevertheless, the mineral compositions of those silicates in the Dalgaranga and Murchison Downs meteorites that have been analysed by modern methods are generally very similar (Table 1). The composition of the pyroxene (Fs_{34}) reported in this work for the Murchison Downs meteorite is identical to that reported for the Dalgaranga meteorite by McCall (1965). While this differs from the pyroxene composition (Fs_{25}) reported for the Murchison Downs meteorite by Hassanzadeh *et al.* (1990), Powell (1971) has shown that pyroxene compositions within individual mesosiderites can be highly variable, though rarely falling outside the range Fs_{20-40}. The compositions of grains of plagioclase can also be variable ranging from An_{80} to An_{98}. McCall (1965) reports an optical determination of plagioclase in the Dalgaranga meteorite with the composition $An_{72}Ab_{28}$ (bytownite) that is very different from analysed plagioclase reported for the Murchison Downs meteorite (Wasson *et al.* 1989; see Table 2), but is also different from the 'anorthite' reported for the Dalgaranga meteorite by Hassandazeh *et al.* (1990).

In contrast to silicates, Powell (1971) and Bunch & Keil (1971) noted that there is generally little compositional variability in chromite for a given mesosiderite. Major oxides in chromite rarely vary by more than 13% of the amounts present, with TiO_2 being the most variable component. Variations in the composition of chromite (notably Al and Mg) between the Murchison Downs and Dalgaranga meteorites are greater than one would normally expect from a single meteorite. However, chromite compositions within fragments of the Dalgaranga meteorite are similarly variable. One grain of chromite associated with a serpentine-group mineral in a weathered portion of the Dalgaranga meteorite showed extreme TiO_2 depletion and MgO and Al_2O_3 enrichment that may be attributed to alteration during severe terrestrial weathering. Simpson (1927) noted one small grain of cohenite in the Murchison Downs meteorite which is confirmed in this work. Minor amounts of cohenite also occur in the Dalgaranga meteorite.

The reported bulk Ni contents of metal in the Dalgaranga meteorite (Table 3) vary from 8.63 %wt (Simpson 1938) to 10.27 %wt (Hassanzadeh *et al.* 1990) consistent with the observed structural heterogeneity of the metallic portions of the meteorite. With the exception of Cr, there is a very close correspondence between the major, minor and trace element contents of metal in the Dalgaranga and Murchison Downs meteorites (Table 3). The Cr content of metal in the Murchison Downs meteorite (221 μg/g) reported by Wasson *et al.* (1989) is 18.5 times greater than that reported by Hassanzadeh *et al.* (1990) for the Dalgaranga meteorite (12 μg/g). This is outside the usual variation in replicate analyses of the same meteorite and could indicate that the two meteorites are distinct. However, it is possible that the high Cr content of the Murchison Downs meteorite reported by Wasson *et al.* (1989) is due to the presence of microscopic inclusions of chromite in the small sample of metal (off WAM 12586) that was analysed (J T Wasson, *pers. comm.*).

On the basis of cluster analysis for a number of elements, notably Ni and Au, in metallic nodules from twelve mesosiderites, Hassanzadeh *et al.* (1990) recognised various sub-groups of mesosiderites. Eight closely related clusters are recognised, and three moderately related clusters are designated low-AuNi, high-AuNi and intermediate-AuNi. Significantly, the Murchison Downs and Dalgaranga meteorites, along with the South Australian mesosiderite, Pinnaroo, form one closely related cluster belonging to the high-AuNi sub-group of mesosiderites (Hassanzadeh *et al.* 1990).

Structurally, the thick band of swathing kamacite that bounds a portion of the exterior surface of the Murchison Downs meteorite is typical of the heterogenous nucleation of this mineral encountered in the metallic nodules from mesosiderites, and indicates that the metal originally formed in contact with either silicates, or some other non-metallic phase. The deformed and locally heat-altered nature of the metallographic structure of Murchison Downs is characteristic of meteorites that have been involved in a crater-forming impact. The style and extent of thermo-mechanical alteration displayed by the Murchison Downs meteorite is identical to that in many of the metallic slugs of the Dalgaranga meteorite. To date, no young meteorite impact crater other than the Dalgaranga crater has been identified in the immediate vicinity of Murchison Downs Station or elsewhere in the Murchison Division of Western Australia.

Summary and Conclusions

The data presented in this paper confirm the re-classification by Wasson *et al.* (1989) of the Murchison Downs meteorite as a mesosiderite but are insufficient to prove, conclusively, that it is a fragment of the Dalgaranga mesosiderite. Notwithstanding, there is little evidence to suggest that they are from different falls. The distance between the find-sites of Dalgaranga and Murchison Downs (*ca.* 200 km) would normally preclude pairing. Mesosiderites are extremely rare and account for less than 1% of all known meteorites. Remarkably, two other mesosiderites (Mount Padbury and Pennyweight) have also been found in the same general area as the Dalgaranga and Murchison Downs meteorites. The suggestion by Mason & Jarosewich (1973) that the Mount

Padbury and Dalgaranga meteorites may be fragments of the same meteorite has been shown by Wasson *et al.* (1974) to be highly unlikely. Also, Hassandazeh *et al.* (1990) show that the Pennyweight and Murchison Downs mesosiderites belong to the low- and high-AuNi sub-groups, respectively, and are probably distinct. However, the discovery in the same general area of two mesosiderites (Dalgaranga and Murchison Downs) that have been involved in crater-forming impact militates against their being from separate falls.

There are a number of explanations as to how the Murchison Downs fragment could have became displaced from the vicinity of the Dalgaranga crater. One possibility is that the Murchison Downs fragment became detached during atmospheric passage of the impacting projectile. However, if this was the case, then the meteorite would not show evidence of damage due to large scale, explosive impact. Moreover, the small size of the Dalgaranga crater (25 m in diameter) makes it very unlikely that the fragment could have been thrown 200 km by the impact event. The most likely explanation is that the fragment was transported by human agency. This could have occurred at any time prior to the discovery of the Murchison Downs meteorite in 1925. The age of the Dalgaranga crater is variably reported from 3000 years (Shoemaker & Shoemaker 1988) to around 25,000 years (Nininger & Huss 1960; Grieve 1991). These ages lie well within the accepted time of Aboriginal occupation of Australia (40,000 years) and it is possible that the impact of the Dalgaranga meteorite was witnessed by Aborigines. Although Aborigines were not known to have collected or utilized meteoritic iron, it is possible that the Murchison Downs meteorite is one of the few examples that have been transported by Aborigines. Pending further work, it is suggested that Murchison Downs be paired with Dalgaranga.

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